The buffering effects of foreign exchange reserves and capital control on international transmission of monetary shocks

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Abstract

This paper uses weekly data to analyze the extent and path of international transmission of monetary policy shocks from the central country to peripheral countries, specifically how monetary shocks affect the risk-adjusted interest rate differentials in peripheral countries. The main conclusions of this paper are presented as follows: first, the change of policy interest rates in the central country (particularly the United States in my paper) will trigger peripheral countries to follow to change their domestic interest rates. Second, when involved in the monetary shocks, peripheral countries with low foreign exchange reserves get higher expected depreciation rates of their domestic currencies, leading their risk-adjusted interest rate differentials to a greater extent of negative deviation from the original value and to a greater fluctuation. It also takes such countries a longer time to reach the steady-state equilibrium of the adjusted differentials. In contrast, peripheral countries with high reserves experience totally divergent situation. Third, this paper proves the "Dilemma", that is, no matter what exchange rate regime a peripheral country chooses to implement, the policy goal of capital account openness sacrifices the goal of monetary policy independence. Last, the analysis of four combinations of different capital control regimes and high or low reserves shows that capital control, along with high reserve hoarding, can help an open economy achieve both independent monetary policy goal and financial stability at the same time.

Keywords: Interest rate shocks; Foreign exchange reserves; Capital control

1 Introduction

The global monetary shocks have occurred many times in the recent 50 years. We can see each time in the monetary shocks caused by the central countries (especially the United States in my paper) , emerging markets and developing countries would respond to international capital flows and their domestic interest rates often (but not always) follow the central country's interest rates to rise or fall. For example, in 1979, Paul Volcker, chairman of the Federal Reserve, announced to curtail the money supply to curb the high level of inflation in the United States. As a result, the interest rates in the US rose rapidly, which led to the debt crisis and the 10-year stagnant economic growth in emerging markets and developing countries. In 2008, after the Global Financial Crisis (GFC), the United States carried out the monetary policy of "Quantitative Easing" (QE) and the US interest rate decreased, followed by a fall of interest rates in many other countries around the world. It can be seen that the monetary policy of central countries has significant impacts on that of peripheral countries.

Therefore, how to restrict the international transmission of interest rate shocks and the monetary shocks from foreign countries has become a key focus. Relevant research can be traced back to the Mundell's "Trilemma". The narrow definition of the "Trilemma" is that an open economy can only achieve two of the three policy goals of independent monetary policy, open capital account and fixed exchange rate. The broad interpretation is that if a country implements the floating exchange rate regime or capital control, it can gain monetary policy autonomy. In other words, the capital control or the floating exchange rate regime can insulate interest rate shocks from abroad.

However, many scholars still hold different opinions on the "Trilemma". Some scholars believe that the implementation of the floating exchange rate regime can provide insulation against international monetary shocks while capital control can only offer limited monetary policy independence (Miniane and Rogers (2007), Klein and Shambaugh (2015) and Obstfeld (2015)). Other literature takes the opposite view, emphasizing the role of capital control in providing autonomy, rather than the floating exchange rate regime. Korinek (2011) and Rey (2013) find that allowing the capital to move freely would expose the economy to irregular global capital flows and such exposure would lead the country to experience volatile cycles of economic boom and bust. Shambaugh (2004) and Obstfeld (2005) emphasize that monetary policy independence is higher under capital control and lower under floating exchange rate regime. Aizenman (2016) also reaches the same conclusion, pointing out the most obvious convergence between the interest rates of the central country and those of the peripheral countries with fixed exchange rate regime and open capital account. Frankel et al. (2004) and Dees and Galesi (2021) believe that countries that choose flexible exchange rate regime cannot realize true monetary policy autonomy goal.

Some other literature questions the binary choices of "corner options" in the classical "Trilemma" theory, arguing that after the Great Recession, many economies are moving towards the "Middle Ground" (Aizenman et al. (2010), Aizenman and Sengupta (2013), Aizenman and Ito (2012), Aizenman (2017) and De la Torre et al. (2002)), which indicates the combination of the managed floating exchange rates, controlled financial integration and viable but limited monetary autonomy. Besides, they also put more emphasis on capital control than floating exchange rate regime to support independent policy.

Because of the Global Financial Crisis and global financial cycle, the "Trilemma" turns out to be replaced by the "Dilemma" – a country can only choose to realize the policy goal of independent monetary policy or capital account openness (Rey (2015)). In this case, as long as there is no capital control, the independence of monetary policy in peripheral countries would be influenced by the central country, regardless of what exchange rate regime peripheral countries carry out. Although the "Dilemma" was first proposed in 2015, it has been discussed before. For instance, Tong and Wei (2011) conclude the same results in line with Rey (2015), even though they do not use the illustration of "Trilemma V.S. Dilemma". Based on both "Trilemma" and "Dilemma", Han and Wei (2018) develop their "2.5-lemma" theory to show that the floating exchange rate regime combined with open capital account can offer policy autonomy to some extent only when the central country raises its interest rates. Nevertheless, the capital control combined with either flexible or fixed exchange rate regime makes policy independent no matter the central country increases or decreases its interest rates.

Based on previous literature research, this paper focuses on international monetary shocks, exploring the extent and path of the impacts of the central country's policy rates (the Federal Funds rates) on peripheral countries' domestic interest rates and the applicability of the "Trilemma" or "Dilemma" in the current era. Central banks in each country (especially in emerging markets and developing countries) want to control their own interest rates. In other words, they focus on the differentials and deviations between their own interest rates and international (the US) rates. Therefore, by analyzing these differentials appropriately adjusted by currency risks and country risks, this paper studies on how international interest rate shocks from the central country to the peripheral countries work. Referring to Shambaugh (2004), Obstfeld (2005) and Wei and Han (2018), dependent monetary policy manifests as the convergence of policy rates between peripheral countries and the central country. When the US policy interest rates change, if peripheral countries' interest rates change in the same direction, I define it as dependent monetary policy in peripheral countries. In the variable setting of this paper, the dependence is embodied in the fact that the variation of risk-adjusted interest rate differentials is less than that of the U.S. interest rates. In testing whether there is the "Dilemma", I introduce the dummy variable of no capital control and multiply it with the variable of monetary shocks from the U.S.. The sign and significance of the coefficient of interaction term represents whether the adoption of floating exchange rate and open capital account helps countries maintain their domestic interest rates unaffected and unchanged in monetary shocks. It can be used to verify which of the "Trilemma" or "Dilemma" holds.

Every economy has different macroeconomic goals (such as slowing down the inflation rate, reducing the unemployment rate) and the target would be lasting for a period of time. To achieve the desired goals, these countries wish to autonomously adjust the interest rate spreads between themselves and the United States to reach the target level and also hopes the spreads to keep stable – not affected by interest rate shocks – in a certain period of time. For example, a country suffering from high inflation would like its interest rate differentials to remain positive for some time until the inflation rate is no longer high. A country with rising unemployment prefers to reduce the differentials and even keep them negative for a period of time. Thus, an open economy needs to consider not only whether it can conduct autonomous monetary policy, but also the stability of the interest rate differentials between itself and the US when facing external monetary policy shocks.

Learning from historical experience and literature, we know that foreign exchange reserves play a role of buffering against the international transmission of interest rate shocks. Since the financial crisis in the 1990s, the Global Financial Crisis and Eurozone

Crisis, most countries, particularly emerging markets, have begun to hoard and manage precautionary international reserves to protect themselves from the "Sudden Stop" of net capital flows and capital flight crisis (Aizenman and Marion (2003), Aizenman and Lee (2007) and Aizenman (2017)). The Asian crisis from 1997 to 1998 caused emerging market economies to store more international reserves as precautionary buffers. Their foreign exchange reserves increased rapidly, especially in East Asian countries and oil exporter countries. By 2020, the world's top ten reserve holding countries include East Asian countries and regions like China (mainland), Japan, Hong Kong (China), South Korea and Singapore; oil exporter countries like Saudi Arabia; developing countries like India, Brazil and Russia; developed countries like Switzerland. In these ten places, China (mainland) hoards $3.162 trillion reserves, accounting for about 40% of the total reserves of the top 10 countries. Aghion et al. (2009), Aizenman and Riera-Crichton (2008), Cespedes and Velasco (2012) and Ricci et al. (2013) argue that if a country manages and handles its foreign exchange reserves properly, it could help enhance its macroeconomic management in the financial turmoils and allow for smoother current account adjustment, which mitigates the impacts of adverse external shocks.

Hence, in order to further verify the buffering role of foreign exchange reserves in the international interest rate shocks, this paper introduces the low reserve dummy variable and the multiplication of the dummy with the Federal Funds rates. Through the coefficient of the cross-term, I explain how international reserves help resist the interest rate shocks on risk-adjusted interest rate differentials. Furthermore, in order to show the shock absorption effects of the international reserves more directly, I also draw the impulse response diagrams of the interest rate differentials responding to monetary shocks between the high and low reserve groups. My results show that, when the central country increases its interest rates, the expected depreciation rates of domestic currencies of the peripheral countries with low reserves rise more, which increases their currency risks. Thus, their risk-adjusted interest rate differentials deviate more negatively from the original value and fluctuate more. On the contrary, when a country with high reserves is involved in monetary policy shocks, due to the low expected currency depreciation, the risk-adjusted interest rate differentials are less volatile. In summary, this paper proves that reserves hoarding can buffer against part of the fluctuation of interest rate differentials caused by interest rate shocks. A series of robustness tests certifies my conclusions. In addition, I also introduce four dummy variables, respectively representing the four combinations of two capital control regimes (capital control or capital account openness) and high or low reserves. I analyze which combination enables an open economy to realize monetary policy independence goal and own nearly stable risk-adjusted interest rate differentials.

This paper makes three contributions. First, unlike most of the previous papers that use annual, quarterly or monthly data, this paper utilizes high-frequency weekly data, aiming at capturing the potential dynamic adjustment process that may be overlooked by low-frequency data. Weekly data also allows me to research more precise extent and path of the impacts of monetary shocks led by the central country on the interest rates and the interest rate differentials in peripheral countries. Second, this paper expands the research of the "Dilemma" and provides empirical evidence for it, proving that only under capital control can an economy have independent monetary policy decisions. Third, I explore the buffering effects of foreign exchange reserves on interest rate differential volatility in international interest rate shocks and explain the mechanism behind, providing ideas for emerging countries and developing countries to realize long-term risk-adjusted interest rate differential stability and financial stability in the period of international interest rate turbulence.

The rest of this article is organized as follows. Section 2 describes empirical models and data. Section 3 presents the empirical results. Specifically, Section 3.1 shows the basic statistics and preliminary tests. Section 3.2 shows the results of the baseline regression equation, which tests the transmission extent of interest rate shocks and the shock absorbing effects of international reserves. In Section 3.3, I do some robustness tests for the baseline regression. In Section 3.4, I further study whether capital control in peripheral countries offers monetary policy independence and the impacts of international reserves combined with capital control. Last, Section 4 is the conclusion of this paper.

2 Models and data

2.1 Empirical models

Referring to Edwards (2010), I build my empirical models. The explained variable that this paper focuses on is the difference between the short-term domestic interest rates of peripheral countries and those of the central country after being appropriately adjusted by country market risks and currency risks. This "risk-adjusted interest rate differential" is defined as follows:

$$x_{i,t} = r_{i,t} - r_t^* - \delta_{i,t} - \rho_{i,t} \tag{1}$$

where $r_{i,t}$ is the nominal interest rate at time t of peripheral country i's securities with a certain maturity issued in i's domestic currency. r_t^* is the nominal interest rate at time t of the central country's (in this paper, the US) securities with the same maturity issued in dollars. $\delta_{i,t}$ is the expected depreciation rate of peripheral country i's currencies at time t. $\rho_{i,t}$ measures the country risks of peripheral country i at time t. The following formula describes the possible dynamic process of the risk-adjusted interest rate differential ($x_{i,t}$):

$$\Delta x_{i,t} = \theta(\tilde{x}_i - x_{i,t-1}) + \sum_{m=1}^{k} \gamma_m y_{mt} + \lambda \Delta x_{i,t-1} + \varepsilon_{i,t} \tag{2}$$

where $\tilde{x}_i$ is the long-term steady-state equilibrium of the interest rate differential for peripheral country i. $x_{i,t-1}$ is the interest rate differential for peripheral country i lagging behind one period. y_{mt} is a vector of shocks with zero-mean and finite-value variance. $\Delta x_{i,t-1}$ is the change of interest rate differentials for peripheral country i lagging behind one period. $\varepsilon_{i,t}$ is an error term. Since this paper focuses on the interest rate shocks from the central country (especially the U.S.), a very important explanatory variable y_{mt} is the change of the U.S. Federal Funds rates. Another focus is whether the coefficient (λ) of the variable $\Delta x_{i,t-1}$ (the change of interest rate differentials with 1-lag period) is significantly different from 0. This coefficient represents the dynamic adjustment process of interest rate differentials. If $\lambda = 0$, the dynamic adjustment is very simple, that is, it only has the characteristic of a partial adjustment process. However, if λ is not equal to 0, the adjustment process will be characterized by oscillation.

In steady-state equilibrium:

$$x_i = \tilde{x}_i \tag{3}$$

Whether the steady-state equilibrium of the interest rate differentials in peripheral country i equals to zero depends on a number of issues, including the degree of capital mobility, as well as other types of market frictions and transaction costs.[1] Only if there is full capital mobility, accurate measurements and no any kinds of transaction costs (e.g. two securities (domestic and foreign) have the same credit risks), the steady-state equilibrium ($\tilde{x}_i$) should be close to 0. In addition, it is also worth paying attention to whether $\tilde{x}_i$ is constant. If $\tilde{x}_i$ is a constant (including zero), any impacts on interest rate differentials will be transitory. If $\tilde{x}_i$ is not a constant, then the long-run equilibrium itself is a function of some exogenous variables, affected by other economic variables. Therefore, this paper also studies on whether the long-term steady-state equilibrium of the interest rate differentials for peripheral country i depends on external shocks like the interest rate level of the U.S. – the U.S. Federal Funds rate level. Thus, I replace $\tilde{x}_i$ in equation (2) and (3) with $\tilde{x}_{i,t}$:

$$\tilde{x}_{i,t} = \alpha + \beta FF_t + \sum_{j=1}^{n} \phi_j Z_{jt} + \omega_{i,t} \tag{4}$$

where FF_t is the level of the U.S. Federal Funds rates at time t. Z_{jt} is other shocks that may determine $\tilde{x}_{i,t}$ (such as global oil price shocks). $\omega_{i,t}$ is the residual. One of the main purposes of the empirical analysis in this paper is to find out whether β and ϕ_j are significantly different from 0.

The most important focus of this paper is on whether international reserves can play a buffering role in the impacts of the US interest rates on the interest rate differentials for peripheral countries. Therefore, I add two cross-terms, an interaction term of the low reserve dummy variable and the change of the Federal Funds rates and another one interaction term of the low reserve dummy variable and the level of the Federal Funds rates. These two cross-terms can clearly show the role of foreign exchange reserves in the international transmission of interest rate shocks.

In summary, the baseline regression model of this paper is as follows:

$$\begin{aligned} x_{i,t} = \alpha + \theta x_{i,t-1} + \gamma_1 ff\_delta_t + \gamma_2 ff\_policy_t + \gamma_3 D_{low} * ff\_delta_t \\ + \gamma_4 D_{low} * ff\_policy_t + \lambda \Delta x_{i,t-1} + \sum_{j=1}^{n} \phi_j Z_{jt} + \varepsilon_{i,t} \end{aligned} \tag{5}$$

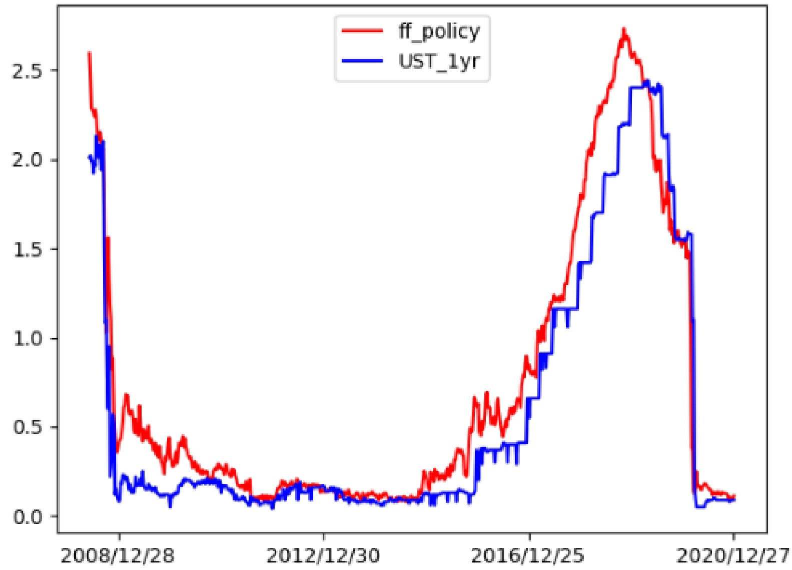
where $x_{i,t}$ is the risk-adjusted interest rate differential of peripheral country i at time t. $x_{i,t-1}$ is the risk-adjusted interest rate differential of peripheral country i at time $t-1$. ff_delta_t is the change of the U.S. Federal Funds rates at time t. ff_policy_t is the level of the U.S. Federal Funds rates at time t. D_{low} is the dummy variable of international reserves, $D_{low} = 1$ if it is in the low reserve group. $\Delta x_{i,t-1}$ is the change of the risk-adjusted interest rate differentials of peripheral country i at time $t-1$. Z_{jt} measures other shocks that may determine the steady-state equilibrium of the differentials (such as global oil price shocks, the change of U.S. Treasury yield curve and the change of dollar value in global financial markets). $\varepsilon_{i,t}$ is an error term.

Before moving to the next part, let me briefly discuss the expected impacts of the Federal Funds rates on the risk-adjusted interest rate differentials of peripheral countries and the role of international reserves in these impacts:

[1] In practice, the equilibrium also depends on the accuracy of measurements. If the accuracy of measurements on country risks and currency risk premiums is poor, the calculated steady-state equilibrium of the interest rate differentials is likely to deviate from 0.

Case 1: The simplest case is that the Federal Reserve's monetary policy actions only influence the interest rates of the United States (r_t^*), that is, the Federal Reserve's policy will neither be transmitted to the domestic interest rates of the peripheral countries, nor to their country risk premiums and currency risk premiums. In this case, $\mathrm{d}x_{i,t}/\mathrm{d}ff_t = -\mathrm{d}r_t^*/\mathrm{d}ff_t$. The variable ff_t in this paper is measured by the Federal Funds rates to capture the monetary policy actions of the Federal Reserve. The variable r_t^* is measured by 1-year Treasury bond yield to capture the U.S. short-term interest rates. The policy actions of the Federal Reserve basically have a 1:1 impact on the U.S. short-term interest rates (see Fig.1), which means $\mathrm{d}r_t^*/\mathrm{d}ff_t \approx 1$. Under this circumstance, $\mathrm{d}x_{i,t}/\mathrm{d}ff_t = -\mathrm{d}r_t^*/\mathrm{d}ff_t \approx -1$.

Fig.1. The Federal Funds policy rates and 1-year US T-bond rates, weekly data, 06/2008—12/2020.



Case 2: If the monetary policy in peripheral countries is not independent, the monetary policy actions of the Federal Reserve may affect the domestic interest rates of peripheral countries ($r_{i,t}$) in addition to the interest rates of the United States (r_t^*). Both effects are positive, implying that peripheral countries will follow the Federal Reserve to raise or decrease their own interest rates.[2] $\mathrm{d}r_{i,t}/\mathrm{d}ff_t > 0$ and $\mathrm{d}r_t^*/\mathrm{d}ff_t > 0$. The increase of domestic interest rates partially or even completely offsets the negative deviation of the risk-adjusted interest rate differentials caused by the rise of U.S. interest rates, resulting in $\mathrm{d}x_{i,t}/\mathrm{d}ff_t = \mathrm{d}r_{i,t}/\mathrm{d}ff_t - \mathrm{d}r_t^*/\mathrm{d}ff_t = \mathrm{d}r_{i,t}/\mathrm{d}ff_t - 1 > -1$. The value of $\mathrm{d}x_{i,t}/\mathrm{d}ff_t$ ranges from -1 to 0 (including 0).

Case 3: This is the most common scenario. The Fed's monetary policy rates affect not only the U.S. short-term interest rates (r_t^*) and the domestic interest rates of the peripheral countries ($r_{i,t}$), but also the expected depreciation rates of peripheral countries' domestic currencies ($\delta_{i,t}$) and their country risks ($\rho_{i,t}$). A rise in the Fed's policy rates leads to carry trades, so that the dollar value rises and the peripheral countries' domestic currency value falls, $\mathrm{d}\delta_{i,t}/\mathrm{d}ff_t \geq 0$. Many scholars' studies (such as Uribe and Yue (2006)) prove that the rise of U.S. policy rates would lead to the increasing country risks in peripheral countries, $\mathrm{d}\rho_{i,t}/\mathrm{d}ff_t \geq 0$. In general, the rise of the Federal Funds rates has three negative effects and one positive effect on the risk-adjusted interest rate differen-

[2] See the positive effects of US policy rates on domestic rates of peripheral countries in Shambaugh (2004), Obstfeld (2005) and Wei and Han(2018).

tials, $\mathrm{d}x_{i,t}/\mathrm{d}ff_t = \mathrm{d}r_{i,t}/\mathrm{d}ff_t - \mathrm{d}r_t^*/\mathrm{d}ff_t - \mathrm{d}\delta_{i,t}/\mathrm{d}ff_t - \mathrm{d}\rho_{i,t}/\mathrm{d}ff_t$. Under this circumstance, $\mathrm{d}x_{i,t}/\mathrm{d}ff_t$ is still negative and its absolute value is less than 1 due to the rise of interest rates in peripheral countries.

In Case 3, the rise of U.S. policy interest rates increases the expected depreciation rates of peripheral countries' currencies. I assume that high reserves can reduce the increase of expected depreciation rates for peripheral countries' currencies, resulting in the reduced exchange rate volatility and then the reduced risk-adjusted interest rate differential volatility, while low reserves cannot play such a buffering role. Hence, I propose another scenario:

Case 3': The Fed's monetary policy interest rates affect the four components of risk-adjusted interest rate differentials: the U.S. interest rates, peripheral countries' domestic interest rates, expected depreciation rates of peripheral countries' domestic currencies and peripheral countries' country risks, $\mathrm{d}x_{i,t}/\mathrm{d}ff_t = \mathrm{d}r_{i,t}/\mathrm{d}ff_t - \mathrm{d}r_t^*/\mathrm{d}ff_t - \mathrm{d}\delta_{i,t}/\mathrm{d}ff_t - \mathrm{d}\rho_{i,t}/\mathrm{d}ff_t$. The value of $\mathrm{d}x_{i,t}/\mathrm{d}ff_t$ ranges between -1 and 0 (including 0). High international reserves lead to lower expected depreciation rates and low reserves lead to higher depreciation rates, $\mathrm{d}\delta_{low\ reserve,t}/\mathrm{d}ff_t > \mathrm{d}\delta_{average,t}/\mathrm{d}ff_t > \mathrm{d}\delta_{high\ reserve,t}/\mathrm{d}ff_t$. Then the risk-adjusted interest rate differentials of low-reserve countries move to more negative direction while those of high reserve countries deviate less negatively from the original value, expressed as $|\mathrm{d}x_{low\ reserve,t}/\mathrm{d}ff_t| > |\mathrm{d}x_{average,t}/\mathrm{d}ff_t| > |\mathrm{d}x_{high\ reserve,t}/\mathrm{d}ff_t|$. In this case, the coefficients of interaction terms should be significantly negative.

2.2 Data and variables

The panel data sample in this paper includes 12 countries, Brazil, Chile, China, Colombia, Hungary, Indonesia, Malaysia, Mexico, Pakistan, Philippines, Poland and Russia. For the sake of data availability and completeness, the sample time span is from June 8, 2008 to December 27, 2020 for all countries except Mexico – from September 16, 2012 to December 27, 2020.

2.2.1 Why weekly data?

The timing of observations plays a key role in analyzing how domestic interest rates are affected by the Fed's monetary policy actions. The Fed's Federal Open Market Committee (FOMC) never has meetings that set interest rates on Fridays. Instead, it usually meets on Tuesdays. The interest rate decision meetings typically last two days, spanning Tuesdays and Wednesdays. When the FOMC releases its rate decisions (on Wednesday or Thursday), some financial markets around the world (such as Asian markets) are already closed on that decision announcement day due to the time difference. When these financial markets eventually respond to the Fed's actions, it is already Friday, the day after the decision day. Therefore, in this paper, I use weekly data and each data point corresponds to every week's Friday data. Thus, this approach of using contemporaneous (same week) data will not cause the problem of time mismatch to analyze the transmission of interest rate shocks.

Table 1: Variable descriptions and data sources

Symbol	Name	Description	Source
$r_{i,t}/dir$	The domestic interest rate	The nominal interest rate at time t of 1-year T-bond issued by the local banking sector in peripheral country i. Weekly data.	www.investing.com
$r_t^*/usir$	The US interest rate	The nominal interest rate at time t of the US 1-year T-bond. Weekly data.	www.investing.com
$\delta_{i,t}/dep$	The expected depreciation rate of domestic currency	The weekly percentage change of the exchange rate of peripheral country i's currency/US dollar at time t. Weekly data.	www.investing.com
$\rho_{i,t}/cdss$	The spread of Credit Default Swaps	The spread of Credit Default Swaps of peripheral country i at time t. Weekly data.	Bloomberg
$x_{i,t}/deviation$	The risk-adjusted interest rate differential	$x_{i,t} = r_{i,t} - r_t^* - \delta_{i,t} - \rho_{i,t}$. Weekly data.	
$x_{i,t-1}/deviation(-1)$	The 1-lag risk-adjusted interest rate differential	The risk-adjusted interest rate differential of peripheral country i at time t-1. Weekly data.	
$\Delta x_{i,t-1}/\Delta deviation(-1)$	The 1-lag change of risk-adjusted interest rate differential	The change of risk-adjusted interest rate differential of peripheral country i at time $t-1$. Weekly data.	
ff_delta_t/ff_delta	The change of the Federal Funds rate	The weekly change of the Federal Funds rate at time t. Weekly data.	www.macrotrends.net
ff_policy_t/ff_policy	The level of the Federal Funds rate	The level of the Federal Funds rate at time t. Weekly data.	www.macrotrends.net
$reserve$	The reserve amount	The total reserves in US dollars excluding gold (in millions) of peripheral country i at time t. Monthly data.	The International Monetary Fund's (IMF) International Financial Statistics (IFS) database
$C(log(reserve))$		The normalized logarithm of reserve amounts. Monthly data.	

Table 1 (continued)

Symbol	Name	Description	Source
gdp	The gross domestic product	The nominal gross domestic product in US dollars (in millions) of peripheral country i at time t. Quarterly data.	The International Monetary Fund's (IMF) International Financial Statistics (IFS) database
$reserve/gdp$	The reserve ratio	The ratio of reserve to GDP of peripheral country i at time t. Monthly data.	
$\Delta log(WTI\_spot(-1))$	The change of the spot WTI crude oil price	The 1-lag change of the logarithm of spot WTI oil price at time t. Weekly data.	www.investing.com
ust_10yr	The level of US Treasury yield	The level of the yield of US 10-year T-bond at time t. Weekly data.	www.investing.com
Δust_10yr	The change of US Treasury yield	The weekly change of the yield of US 10-year T-bond at time t. Weekly data.	www.investing.com
Δusd_eur	The change of dollar value	The weekly percentage change of the exchange rate of Dollar/Euro at time t. Weekly data.	www.investing.com
$kaopen$	The KAOPEN index	The degree of capital account openness of peripheral country i at time t. Between 0 and 1 (0 and 1 included). The closer to 0, the more capital control. Annual data.	Chinn and Ito (2006, 2008)
ka	The ka index	The degree of capital control of peripheral country i at time t. Between 0 and 1 (0 and 1 included). The closer to 1, the more capital control. Annual data.	Fernández et al. (2015)
$g_{i,t}/int\_dif$	The unadjusted interest rate differential	$g_{i,t} = r_{i,t} - r^*_t$. Weekly data.	
$g_{i,t-1}/int\_dif(-1)$	The 1-lag unadjusted interest rate differential	The unadjusted interest rate differential of peripheral country i at time $t-1$. Weekly data.	
$\Delta g_{i,t-1}/\Delta int\_dif(-1)$	The 1-lag change of unadjusted interest rate differential	The change of unadjusted interest rate differential of peripheral country i at time $t-1$. Weekly data.	

2.2.2 The explained variable – the risk-adjusted interest rate differentials

The main explained variable of this paper is the risk-adjusted interest rate differentials ($deviation/x_{i,t}$): $x_{i,t} = r_{i,t} - r_t^* - \delta_{i,t} - \rho_{i,t}$, where $r_{i,t}$ is the nominal interest rate at time t of 1-year T-bond issued by the local banking sector in peripheral country i. r_t^* is the nominal interest rate at time t of the U.S. 1-year T-bond. $\delta_{i,t}$ is the actual domestic currency depreciation rate in peripheral country i at time t, measured by the weekly percentage change of the exchange rate of peripheral country i's currency/US dollar. $\rho_{i,t}$ is measured by the spread of Credit Default Swaps of peripheral country i at time t. All of the data is weekly data. Please refer to Table 1 for detailed data descriptions and sources.

Fig.2. Interest rate differentials in selected 12 countries, weekly data, 06/2008—12/2020.

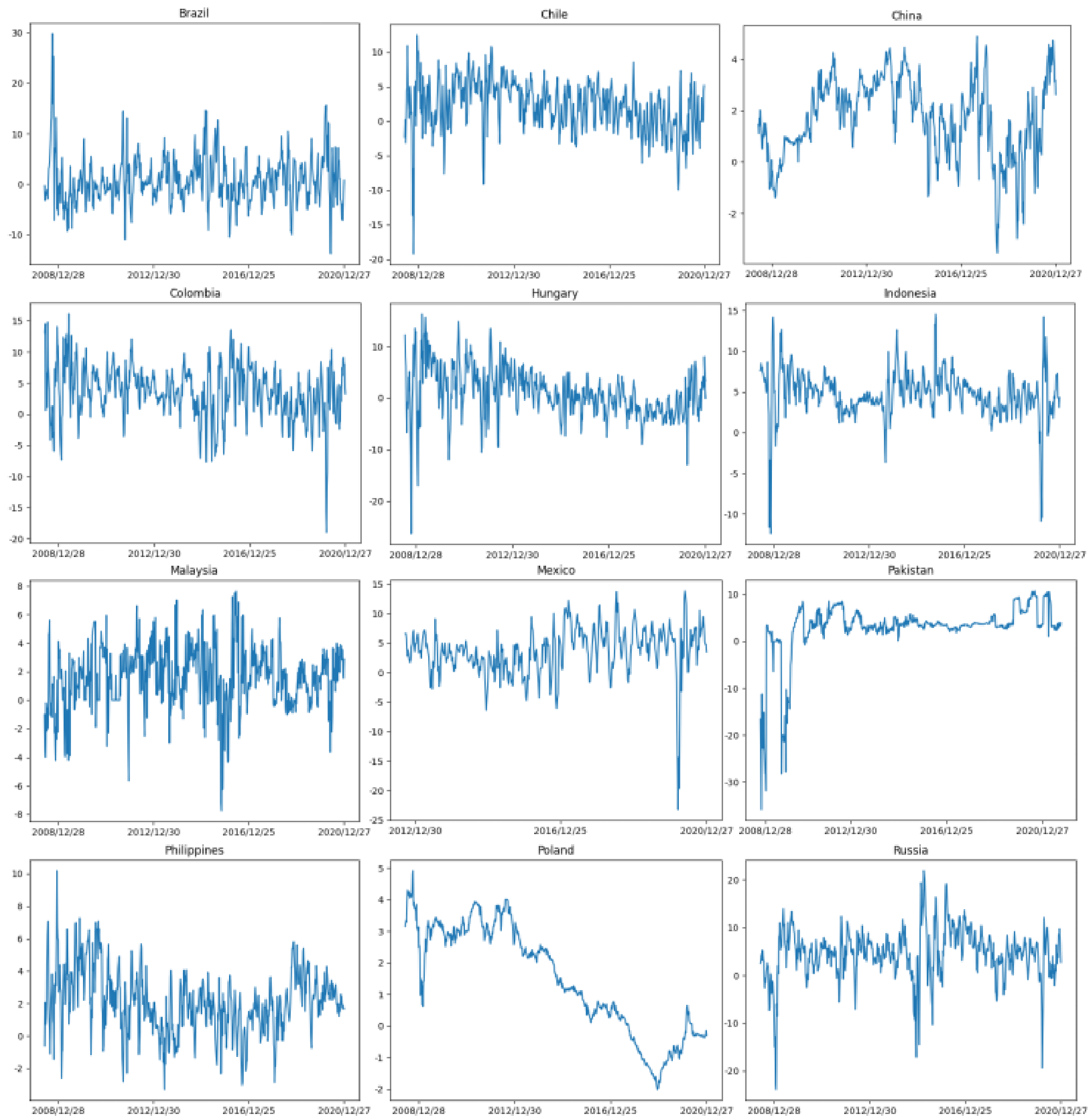


Fig.2 shows the risk-adjusted interest rate differentials for the 12 countries in my sample. Since the spreads of Credit Default Swaps only capture a limited degree of sovereign country risk premiums, the actual calculation of Eq.(1) excludes a residual credit risk premium that is not captured by the CDS spreads. Therefore, we can expect that the differentials computed by Eq.(1) are positive in most of the sample time. As can be seen from Fig.2, most of the risk-adjusted interest rate differentials are positive in 12 countries over the sample time interval.

In the robustness tests, I replace the explained variable with "unadjusted interest rate differentials" ($int\_dif/g_{i,t}$) to ascertain that the foreign exchange reserves influence the risk-adjusted interest rate differentials definitely through the channel of the expected domestic currency depreciation rates. The unadjusted interest rate differential is computed as follows: $g_{i,t} = r_{i,t} - r_t^*$, where the interest rates of the peripheral countries ($r_{i,t}$) and those of the central country (r_t^*) are defined as above. Similarly, I replace the other variables related to risk-adjusted interest rate differentials variable in the baseline regression with the unadjusted interest rate differentials lagging 1 period ($int\_dif(-1)/g_{i,t-1}$) and the change of the unadjusted interest rate differentials lagging 1 period ($\Delta int\_dif(-1)/\Delta g_{i,t-1}$).

2.2.3 The explanatory variables

As for the key explanatory variable – the U.S. monetary policy interest rates, I refer to Edwards (2010) to use U.S. Federal Funds rates. The weekly data of the change and the level of the Federal Funds rates are denoted as ff_delta_t and ff_policy_t respectively. In order to specifically reflect the dynamic adjustment process of the differentials, I also introduce the lagged interest rate differentials ($deviation(-1)/x_{i,t-1}$) and the lagged interest rate differential changes ($\Delta deviation(-1)/\Delta x_{i,t-1}$). All are weekly data.

Another one variable that this paper focuses on, international reserves, are measured by total reserves in US dollars excluding gold from the International Monetary Fund's (IMF) International Financial Statistics (IFS) database. Due to the data availability, I can only get monthly reserve data. Thus, I have to assume that reserves are the same in every week of a month, equal to this month's reserve amounts. I admit that it is for sure not precise enough. However, since the change of reserve amounts during a month is not too much, even if I only obtain the monthly data, my results still have much significance. In most regressions, the way I use to classify high and low reserve groups is to sort the international reserves in ascending order and select the first 50% data as low reserve group and the other half as high reserve group. Then I introduce a dummy variable. For low reserve group, $D_{low} = 1$ and $D_{low} = 0$ for high reserve group. To ensure the accuracy of the results, I also use another criterion to make classification in some regressions. I use the ratio of reserves to GDP to group the panel data into low and high reserve groups. Similarly, I rank the ratio in ascending order, taking the top 50% as low reserve group, $D_{low} = 1$, the bottom 50% as high reserve group, $D_{low} = 0$. GDP data is also collected from the International Monetary Fund's (IMF) International Financial Statistics (IFS) database. Since the minimum statistical frequency of GDP is quarterly, I have to assume that GDP is constant in each week of the same quarter and all equal to the GDP value of the current quarter. Such an assumption undoubtedly damages the accuracy of grouping. In the robustness tests, I use other thresholds to classify high and low reserve groups, such as 2/3, 2/5 and the median. Besides, I replace the low reserve dummy variable with the continuous reserve variable and add it to the cross-term. The procedure of processing continuous reserve variable is to first take the logarithm of reserve amounts and then normalize (or centralize) the logarithm, denoted as $C(log(reserve))$. The regression results are presented in detail in the robustness tests section.

Other exogenous variables that can affect the interest rate differentials are: (1) The change in the spot WTI crude oil price ($\Delta log(WTI\_spot(-1))$): another global shock, measured by the change of the logarithm of spot WTI oil price with 1-stage lag, weekly data. (2) The level and change of the yield curve of the US long-term T-bond (ust_10yr and Δust_10yr respectively): measured by the level and the change of the yield of the US 10-year T-bond, weekly data. (3) The change of US dollar value in global financial markets (Δusd_eur)[3]: measured by the weekly percentage change of the exchange rate of Dollar/Euro at time t. This variable will affect the risk-adjusted interest rate differentials by influencing the expected depreciation rates of currencies in peripheral countries. The rise of Δusd_eur means that the dollar depreciates and the depreciation rates of domestic currencies decrease, forcing the interest rate differentials to deviate positively from the original value.

In the last part of my empirical research, I explore the role of the combination of capital control regimes and international reserves in interest rate shocks. There are two ways to measure capital control: The first is the KAOPEN index from Chinn and Ito (2006, 2008).[4] It measures the openness of the capital account, ranging from 0 to 1 (0 and 1 included). The closer it gets to 1, the more open the capital account is and the more unrestricted capital flows are. Otherwise, the capital account is more closed and subject to capital control. I sort KAOPEN index in ascending order, selecting the top 50% data as the capital control group and the bottom 50% data as the group without capital control. Then I introduce no capital control dummy variable, $D_{NC} = 1$ for no capital control group, otherwise, $D_{NC} = 0$. In the robustness tests, I use continuous KAOPEN index instead of the dummy variable. Since the KAOPEN index is already standardized between 0 and 1, I do not need to standardize the continuous variable of KAOPEN as I deal with the continuous reserve variable. The other one to measure capital control is the ka index coming from Fernandez et al. (2015).[5] I choose the most inclusive capital control index, ka, which measures the total control for both capital inflows and outflows in all types of assets. It also ranges between 0 and 1 (0 and 1 included). The value closer to 1 means more capital control. On the contrary, capital flows move more freely. According to the method mentioned before, I also select half of the data as the no capital control group, $D_{NC} = 1$, the other half as the capital control group, $D_{NC} = 0$. Importantly, the frequency of both indexes is annual. I have to assume that the level of capital control for each week within a year is equal to the capital control level of that year. Like the problems that other scholars who use high-frequency data to do research on capital control encounter, I cannot avoid the inaccuracy of using annual capital control indexes for weekly observations.

[3]The index used to measure the dollar value should have be the Federal Reserve's Trade Weighted Index of the USD (Edwards (2010)). However, this paper uses high-frequency weekly data and the index mentioned in the preceding sentence cannot reach such a high-frequency level.

[4]The KAOPEN index refers to the information about restrictions in the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). This index is the first standardized principal component variable used to represent the presence of various controls, such as restrictions on capital account transactions.

[5]Developing on the data from Schindler (2009) and the AREAER, Fernandez standardizes the treatment of capital control on 10 asset classes (regardless of inflows or outflows). This index distinguishes not only the degree of control for different categories of assets, but also the degree of control for capital inflows and outflows.

3 Empirical results

3.1 Basic statistics and preliminary tests

Table 2 shows the descriptive statistics of risk-adjusted interest rate differentials for 12 countries in my sample, with the mean of differentials greater than 0 in all countries. Table 3 presents the unit root tests for my sample panel data. Through three methods of unit root tests (IPS, ADF-Fisher and PP-Fisher), the null hypothesis of unit root is rejected. Table 4 shows the descriptive statistics for all variables.

Table 2: Interest rate differentials in selected 12 countries: descriptive statistics, weekly data, 06/2008—12/2020.

	Brazil	Chile	China	Colombia	Hungary	Indonesia
Mean	0.808	2.270	1.687	3.562	0.945	4.760
Median	0.255	2.725	1.832	3.710	0.636	4.731
Maximum	29.770	12.501	4.902	16.141	16.287	14.594
Minimum	-13.750	-19.224	-3.540	-18.962	-26.297	-12.412
Variance	22.423	13.696	2.332	17.710	22.006	8.265
Std. Dev.	4.735	3.701	1.527	4.208	4.691	2.875
Skewness	1.008	-0.790	-0.450	-0.568	-0.071	-0.980
Kurtosis	6.719	5.345	2.966	4.852	5.062	10.451
Jarque-Bera statistic	489.103	212.490	22.005	128.765	115.895	1612.622
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Observations	643	643	643	643	643	643

	Malaysia	Mexico	Pakistan	Philippines	Poland	Russia
Mean	1.642	3.662	3.239	2.078	1.441	4.576
Median	1.743	4.135	3.546	1.985	1.360	4.798
Maximum	7.652	13.869	10.770	10.182	4.910	21.913
Minimum	-7.751	-23.201	-35.876	-3.303	-2.011	-23.921
Variance	5.078	16.745	30.176	3.783	2.897	27.195
Std. Dev.	2.254	4.092	5.493	1.945	1.703	5.215
Skewness	-0.456	-1.353	-3.957	0.223	-0.167	-0.952
Kurtosis	4.023	9.866	22.262	3.417	1.759	7.499
Jarque-Bera statistic	47.049	978.063	10918.681	10.202	44.638	648.225
P-value	0.000	0.000	0.000	0.006	0.000	0.000
Observations	643	431	643	643	643	643

3.2 Reserves and the international transmission of interest rate shocks

Table 5 shows the results of the baseline regression Eq.(5) using panel data of 12 countries. In Column (1) - Column (5), the classification method of high and low reserve groups is to sort the reserve amounts from low to high, selecting the data in the first 50% as the low reserve group and the else as the high reserve group. In Column (6) - Column (7), I use the ratio of reserves to GDP to classify. In the empirical analysis part, all equations are estimated using GMM estimate to solve the endogeneity problem of the lag terms. In the robustness tests of the baseline equation, referring to Edwards (2010), I use the GLS estimate with country fixed effect.

Table 3: Unit root tests, weekly data, 06/2008—12/2020.

Method	Statistic	Prob.***	Cross-section	Observation
Null: unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-12.1697	0.0000	12	7504
ADF-Fisher chi-square	31.8659	0.0000	12	7504
PP-Fisher chi-square	73.1311	0.0000	12	7504

Table 4: Description statistics of all variables

Variable	Obs	Mean	Std. Dev.	Min	Max
dir	7547	5.239	3.26	0.006	16.416
$usir$	7642	0.728	0.79	0.078	2.731
dep	7642	0.895	3.872	-17.327	32.809
$cdss$	7594	1.046	2.284	0.03	44.675
$deviation$	7504	2.526	3.997	-35.875	29.77
$deviation(-1)$	7504	2.526	3.999	-35.875	29.77
$\Delta deviation(-1)$	7504	-0.001	2.342	-19.57	24.282
ff_policy	7641	0.595	0.748	0.04	2.44
ff_delta	7641	-0.003	0.077	-0.95	0.35
$reserve$	7642	384455.15	858832.92	4381.88	4010833.5
$C(log(reserve))$	7642	0.000	1.423	-3.202	3.617
gdp	6330	444310.3	778803.7	26646.1	4466765
$reserve/gdp$	6330	0.794	0.325	0.341	1.933
$\Delta log(WTI\_spot(-1))$	6330	-0.002	0.068	-0.821	0.504
ust_10yr	7642	2.38	0.762	0.533	4.261
Δust_10yr	7642	-0.005	0.117	-0.508	0.412
Δusd_eur	7642	-0.029	1.331	-5.85	5.09
$kaopen$	7020	0.481	0.255	0.164	1
ka	7020	0.6	0.252	0.075	1
int_dif	7547	4.508	3.353	-2.381	16.059
$\Delta int\_dif(-1)$	7547	4.511	3.354	-2.381	16.059
$int\_dif(-1)$	7547	-0.001	0.716	-12.96	12.933

Column (1) is the simplest regression. The explanatory variables are only the adjusted interest rate differentials with 1-lag ($deviation(-1)$) and the change of the Federal Funds rates (ff_delta), where the coefficient of the latter variable represents the short-term impacts of the Fed's monetary policy actions on the differentials. In Column (2), I add the level of the Federal Funds rates (ff_policy), whose coefficient represents the long-term impacts of US policy rates on the adjusted differentials. In Column (3), I introduce the change of spot WTI oil price ($\Delta log(WTI\_spot(-1))$) as another shock that may affect the differentials by influencing the inflation or inflation expectations. In Column (4), the cross-term $D_{low} * ff\_delta$ and the cross-term $D_{low} * ff\_policy$ are added to explore the direction and extent of deviation of the interest rate differentials for peripheral countries with low reserves under interest rate shocks originating from the United States. In Column (5), I add 1-lag change of the adjusted differentials ($\Delta deviation(-1)$) for more common dynamic adjustment process.

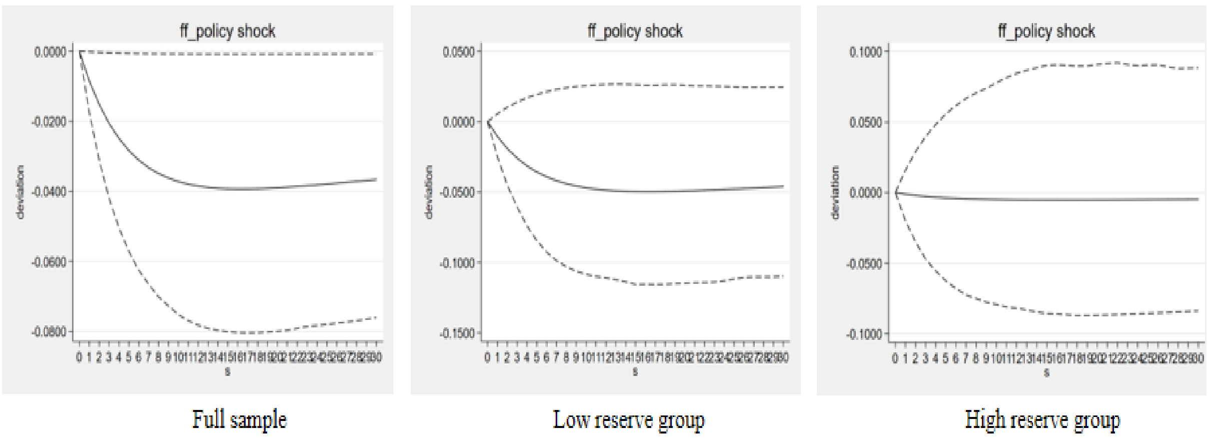
Table 5: The results of the baseline regression, GMM estimate.

	(1)Reserve	(2)Reserve	(3)Reserve	(4)Reserve	(5)Reserve	(6)Reserve ratio	(7)Reserve ratio
VARIABLES	deviation	deviation	deviation	deviation	deviation	deviation	deviation
$deviation(-1)$	0.844***	0.842***	0.817***	0.816***	0.800***	0.817***	0.801***
	(0.014)	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
ff_delta	0.059	0.091	0.114	0.046	-0.039	-0.530	-0.419
	(0.662)	(0.661)	(0.707)	(0.882)	(0.855)	(0.501)	(0.487)
ff_policy		-0.099***	-0.140***	-0.081**	-0.087**	-0.177***	-0.189***
		(0.030)	(0.035)	(0.038)	(0.038)	(0.041)	(0.041)
$\Delta log(WTI\_spot(-1))$			0.482	0.479	0.308	0.505	0.331
			(0.731)	(0.731)	(0.741)	(0.732)	(0.741)
$D_{low} * ff\_delta$				0.129	0.222	1.202	0.933
				(1.400)	(1.384)	(1.330)	(1.317)
$D_{low} * ff\_policy$				-0.144***	-0.152***	-0.168***	-0.175***
				(0.052)	(0.052)	(0.049)	(0.049)
$\Delta deviation(-1)$					0.078***		0.077***
					(0.022)		(0.022)
Constant	0.394***	0.457***	0.549***	0.555***	0.602***	0.551***	0.597***
	(0.047)	(0.056)	(0.062)	(0.062)	(0.063)	(0.062)	(0.063)
Observations	7422	7422	6250	6250	6209	6250	6209
Number of id	12	12	12	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

As can be seen from Table 5, the coefficients of the 1-lag interest rate differentials ($deviation(-1)$) in every column are all less than 1, confirming the results of unit root tests and indicating the existence of convergence. The coefficient of Federal Funds rate change (ff_delta) in Column (2) is not significant, proving that the temporary change of Federal Funds rates has no significant impacts on the risk-adjusted interest rate differentials. In Column (3), the coefficient of Federal Funds rate change (ff_delta) is still not significant. However, the coefficient of the Federal Funds rate level (ff_policy) is significantly -0.099 at 1% level, showing that the permanent change of the Federal Funds rates has permanent impacts on the differentials. The absolute coefficient value of ff_policy is less than 1, which proves that the change of the Federal Funds rates affects not only US short-term interest rates, but also the domestic interest rates of peripheral countries. When the US policy rates rise, the interest rates of peripheral countries will also rise, making $\mathrm{d}x_{i,t}/\mathrm{d}ff_t > -1$. In Column (3), the variable of oil price shocks is added but its coefficient is not significant, saying that the change of oil prices has no significant effects on interest rate differentials. The coefficient of variable ff_policy is still significant at 1% level and greater than -1, which confirms that permanent change of the Federal Funds rates does not have a "1-to-1" effect on the risk-adjusted interest rate differentials. The Column (4) proves the hypothesis of this paper. This paper focuses on the role of foreign exchange reserves in the transmission channel from Federal Funds rates to adjusted interest rate differentials. It can be seen that the coefficient of interaction term $D_{low} * ff\_delta$ is not significant, indicating that reserves cannot impact on the way that short-term change of US interest rates works on the differentials. However, the coefficient of cross-term $D_{low} * ff\_policy$ is -0.144 and significant at 1% level, verifying the conjecture in this paper: Reserves buffer against monetary shocks and affect the differentials by influencing the risk of currency devaluation. To be specific, low reserves increase the expected depreciation rates of domestic currencies in peripheral countries (i.e. $\mathrm{d}\delta_{i,t}/\mathrm{d}ff_t$ increases) and then the currency risks, which leads to the increase of the extent of negative deviation from the original differential's value (i.e. $\mathrm{d}x_{i,t}/\mathrm{d}ff_t$ is more negative). Similarly, on the contrary, the expected currency depreciation rates of high reserve countries is reduced (i.e. $\mathrm{d}\delta_{i,t}/\mathrm{d}ff_t$ decreases) , so is their domestic currency depreciation risk. This reduction offsets part of the negative deviation of risk-adjusted interest rate differentials caused by the rise of the Federal Funds rates. The results of Column (5) are consistent with those of the previous columns. The coefficient of 1-lag change of interest rate differentials introduced ($\Delta deviation(-1)$) is significantly positive, which means a complex dynamic adjustment process for the differentials. The results of Column (6) and Column (7) grouping high and low reserve groups with the ratio of reserves to GDP square with the expectations of this paper. They again show that low international reserves make peripheral countries' interest rate differentials deviate more negatively from the original value under the rise of US interest rates.

Fig.3. The impulse response diagrams.



Next, in order to visually show the response of risk-adjusted interest rate differentials in peripheral countries to the interest rate shocks, I draw three impulse response diagrams (Fig.3). These three are figures for the whole sample, the low reserve group sample and the high reserve group sample. The questions discussed are: what is the difference between the high and low reserve groups in the transmission path of the Federal Funds rates to the risk-adjusted differentials? What is the difference in the extent of such a shock? Does it take different time for two groups to reach the steady-state equilibrium?

Four aspects of the impulse response diagrams are noteworthy. First of all, in all three pictures, the risk-adjusted interest rate differentials deviate negatively from the original value. As the results shown in Table 5, the effects of a rise of Federal Funds rates on the differentials are negative. Specifically, all interest rate differentials deviate negatively from the original value by less than 1. It confirms that the domestic interest rate in

Table 6: Adding more shocks, GMM estimate.

	(1)	(2)	(3)	(4)
VARIABLES	deviation	deviation	deviation	deviation
$deviation(-1)$	0.800***	0.799***	0.800***	0.801***
	(0.015)	(0.013)	(0.015)	(0.015)
ff_delta	-0.039	-0.077	0.046	-0.083
	(0.855)	(0.858)	(0.852)	(0.862)
ff_policy	-0.087**	-0.093**	-0.084**	-0.093**
	(0.038)	(0.038)	(0.038)	(0.037)
$\Delta log(WTI\_spot(-1))$	0.305	0.311	0.402	0.415
	(0.742)	(0.745)	(0.722)	(0.715)
$D_{low} * ff\_delta$	0.219	0.263	-0.038	-0.028
	(1.384)	(1.383)	(1.328)	(1.314)
$D_{low} * ff\_policy$	-0.152***	-0.158***	-0.149***	-0.125**
	(0.052)	(0.052)	(0.051)	(0.051)
$\Delta deviation(-1)$	0.078***	0.079***	0.078***	0.075***
	(0.023)	(0.022)	(0.022)	(0.022)
Δust_10yr	0.045	0.014	0.156	0.149
	(0.330)	(0.332)	(0.327)	(0.319)
ust_10yr		0.061	0.091*	0.092*
		(0.048)	(0.047)	(0.047)
Δusd_eur			0.296***	0.048
			(0.030)	(0.043)
$D_{low} * \Delta usd\_eur$				0.472***
				(0.057)
Constant	0.602***	0.464***	0.390***	0.389***
	(0.063)	(0.128)	(0.125)	(0.125)
Observations	6209	6209	6209	6209
Number of id	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

peripheral countries has risen rapidly in response to the rise of the Fed's monetary policy rate but the former one is not high enough to fully offset the latter one. The monetary policy in peripheral countries lacks independence. Second, the new long-term equilibrium of the interest rate differentials in the whole sample is about -0.04. Although there is a slight rebound, it still proves that the rise of the Federal Funds rates leads to a permanent negative deviation for the interest rate differentials, which is 0.04% in the long-term equilibrium. Third, the negative deviation degree of interest rate differentials in the low reserve group (0.05%) is much higher than that in the high reserve group (less than 0.005%, almost 1/10 of the negative deviation degree in the low reserve group). Although the deviation in the low reserve group is slightly reduced in the long run, it is still greater than that in the high reserve group. These figures directly show that higher international reserves can reduce the deviation degree of adjusted interest rate differentials when the US monetary policy rates change, that is, reducing the differentials' volatility and absorbing interest rate shocks. Fourth, the adjusted differentials of low reserve group reach steady-state for a longer period of time (about 14 periods) and are unstable, rebounding at the

21st period. On the other hand, the differentials of high reserve group become stable at the 8th period which is about half of the time for low reserve group, It shows that the interest differentials of the high reserve group adjust faster.

Then, I introduce more shocks, examining how the changes of US Treasury yield curve and dollar value in global financial markets impact on the risk-adjusted interest rate differentials for the 12-country sample. The shocks brought by the change of Treasury yield curve are measured by the change and the level of the US 10-year Treasury yield, expressed as Δust_10yr and ust_10yr respectively. The variable that measures the change of dollar value is expressed as Δusd_eur. High and low reserve groups are divided according to the reserve amounts. The regression results are shown in Table 6. After the inclusion of additional explanatory variables, the previous conclusions (see Table 5 for details) remain unchanged: Interest rates of peripheral countries rise with the rise of the Federal Funds rates, resulting in the coefficient of ff_policy greater than -1. Compared with high reserve group, low reserves cannot cushion and even magnify the negative deviation of peripheral countries' interest rate differentials caused by the rise of the Federal Funds rates. In Column (1), the coefficient of the change of US long-term interest rates (Δust_10yr) is not significant, indicating that a steeper yield curve in the short term does not have a significant effect on risk-adjusted differentials when the Federal Funds rates remain unchanged. In Column (2), the coefficients of the change (Δust_10yr) and level (ust_10yr) of the US 10-year Treasury yield are not significantly different from zero, which means that the US Treasury yield shocks have little impact on the spreads, whether it is short-term or long-term. We can see from the Column (3) that the impacts of the dollar value shocks are very violent. The change of Dollar/Euro exchange rate (Δusd_eur) has a significant effect on interest rate differentials and the coefficient is positive significantly at 1%. This can be explained by the facts that a temporary fall of dollar value (positive Δusd_eur) lowers the expected domestic currency depreciation rates, resulting in a positive deviation of differentials, as expected. Moreover, the focus of this paper is also reflected on this variable. In Column (4), the coefficient of cross-term $D_{low} * \Delta usd\_eur$ is positive and significant at 1%. It illustrates that low reserves cannot buffer against exchange rate shocks. They are unable to reduce the impacts on interest rate differentials caused by the dollar value volatility, making the deviation degree of risk-adjusted interest rate differentials bigger. Unlike low reserves, higher reserves can cushion the impacts originating from exchange rate fluctuations, making interest rate spreads less volatile.

Since this paper wants to study the way of reserves affecting interest rate differentials – the expected depreciation rates of domestic currencies, I further select samples with larger depreciation rate variations (i.e. the floating exchange rate regime sample). The method for selecting the sample of floating exchange rate regime is as follows: if the monthly change of exchange rate is within $\pm 0.33\%$, then I define the month as a fixed exchange rate regime month; Similarly, if the absolute value of the monthly change exceeds 0.33%, I define the month as a floating exchange rate regime month.[6] By applying this threshold to exchange rate changes, I obtain a new sample of floating exchange rate regime. I re-classify the high and low reserve groups for the new sample in the same way I use in the baseline regression. Then, I use GMM estimate on Eq.(5) again. The results are shown in Table 7. It can be seen that the main conclusions are also applicable to the sample of floating exchange rate regime: There is a convergence of risk-adjusted interest rate spreads; Temporary change of the Federal Funds rates has no significant effects on

[6]This method of classification between floating and fixed exchange rate regimes has been accepted by many scholars (such as Aizenman (2015)).

the interest rate spreads (the coefficient of ff_delta is not significant), but permanent change of the Federal Funds rates has significant effects on the spreads (the coefficient of ff_policy is significant at least at 10%); The coefficient of the Federal Funds rate level (ff_policy) is greater than -1, meaning that the interest rates in peripheral countries also rise after the rise of U.S. policy rates; The coefficient of $D_{low} * ff\_policy$ is negative and significant at 1%, indicating that the lower the reserves are, the greater deviation of the differentials from the original value will be; The coefficient of the 1-lag change of interest rate differentials ($\Delta deviation(-1)$) is significantly positive, showing a complex dynamic adjustment process; The impacts of dollar value shocks are positive significantly at 1% and the coefficient of the cross-term $D_{low} * \Delta usd\_eur$ is also positive at 1% significance level, which demonstrates that low reserves cannot buffer against the deviation of interest rate differentials caused by currency risks.

Table 7: The floating exchange rate regime sample, GMM estimate.

	(1)	(2)	(3)	(4)
VARIABLES	deviation	deviation	deviation	deviation
$deviation(-1)$	0.819***	0.800***	0.801***	0.801***
	(0.015)	(0.016)	(0.016)	(0.016)
ff_delta	0.169	-0.102	-0.110	-0.208
	(0.816)	(1.015)	(1.012)	(1.023)
ff_policy	-0.139***	-0.078*	-0.077*	-0.085**
	(0.039)	(0.042)	(0.042)	(0.042)
$\Delta log(WTI\_spot(-1))$	0.558	0.369	0.468	0.487
	(0.830)	(0.842)	(0.819)	(0.812)
$D_{low} * ff\_delta$		0.432	0.169	0.108
		(1.589)	(1.525)	(1.506)
$D_{low} * ff\_policy$		-0.167***	-0.165***	-0.143***
		(0.056)	(0.055)	(0.054)
$\Delta deviation(-1)$		0.082***	0.082***	0.079***
		(0.024)	(0.023)	(0.023)
Δust_10yr			0.334	0.285
			(0.374)	(0.365)
ust_10yr			0.113	0.115
			(0.542)	(0.537)
Δusd_eur			0.323***	0.051
			(0.033)	(0.052)
$D_{low} * \Delta usd\_eur$				0.489***
				(0.065)
Constant	0.555***	0.614***	0.354**	0.348**
	(0.069)	(0.070)	(0.141)	(0.140)
Observations	5362	5362	5362	5362
Number of id	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

3.3 Robustness tests

In this section, I use five methods to test the robustness of the baseline regression. First of all, in order to test the robustness of grouping, I re-divide the low reserve amount group and the low reserve ratio group of the whole sample, changing the threshold from 1/2 to median, 2/3 and 2/5. Second, I replace the dummy variable (D_{low}) with the continuous reserve variable and form new cross-terms $C(log(reserve)) * ff\_delta$ and $C(log(reserve)) * ff\_policy$. The $C(log(reserve))$ variable is measure by the standardized logarithmic reserve amounts. Third, I use GLS estimate with country fixed effect to re-estimate the baseline regression, whose grouping criteria are still the reserve amounts and the reserve ratios. Fourth, I select 2010 to 2020 as the new time span. The time span for the baseline regression includes the Global Financial Crisis of 2008, the year of severe turmoil in financial markets following the collapse of Lehman Brothers and the initial rejection of the Troubled Asset Relief Programme (TARP) by Congress. To avoid the possible impacts of the 2008 financial crisis and its aftermath, I exclude 2008 and 2009. Finally, I replace the dependent variable with the "unadjusted interest rate differentials", expressed as $g_{i,t}$, to prove that the way that reserves affect the risk-adjusted interest rate differentials is indeed the channel of affecting the expected depreciation rates of domestic currencies.

Table 8: Robustness regression—different grouping thresholds.

	(1)Reserve, median	(2)Reserve, 2/3	(3)Reserve, 2/5	(4)Reserve ratio, median	(5)Reserve ratio, 2/3	(6)Reserve ratio, 2/5
VARIABLES	deviation	deviation	deviation	deviation	deviation	deviation
$deviation(-1)$	0.800***	0.799***	0.799***	0.801***	0.801***	0.801***
	(0.015)	(0.013)	(0.015)	(0.015)	(0.015)	(0.015)
ff_delta	-0.039	-0.197	0.038	-0.419	-0.141	-0.419
	(0.855)	(1.095)	(0.763)	(0.487)	(0.638)	(0.487)
ff_policy	-0.087**	-0.050	-0.089**	-0.189***	-0.126**	-0.189***
	(0.038)	(0.046)	(0.036)	(0.041)	(0.051)	(0.041)
$\Delta log(WTI\_spot(-1))$	0.308	0.313	0.301	0.331	0.309	0.331
	(0.741)	(0.741)	(0.740)	(0.741)	(0.740)	(0.741)
$D_{low} * ff\_delta$	0.222	0.447	0.085	0.933	0.302	0.933
	(1.384)	(1.412)	(1.455)	(1.317)	(1.122)	(1.317)
$D_{low} * ff\_policy$	-0.152***	-0.166***	-0.178***	-0.175***	-0.127**	-0.175***
	(0.052)	(0.052)	(0.057)	(0.049)	(0.053)	(0.049)
$\Delta deviation(-1)$	0.078***	0.078***	0.078***	0.077***	0.077***	0.077***
	(0.022)	(0.022)	(0.023)	(0.022)	(0.022)	(0.022)
Constant	0.602***	0.602***	0.603***	0.597***	0.594***	0.597***
	(0.063)	(0.063)	(0.063)	(0.063)	(0.062)	(0.063)
Observations	6209	6209	6209	6209	6209	6209
Number of id	12	12	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

In the baseline regression, I use the full sample, defining top 50% data after sorting the reserve amounts and reserve ratios in ascending order as the low reserve group. To test whether the baseline results would have different results due to different grouping thresholds, I re-classify low and high reserve groups with three different thresholds (median, 2/3 and 2/5) to do robustness tests. In Table 8, the regression results are similar to the benchmark regression results, both indicating that low reserves make the risk-adjusted interest rate spreads fluctuate more, while high reserves do not. This table shows that no matter how I define the high and low reserve groups, the baseline regression results are still robust.

Unlike the cross-term in the previous section, I now replace the dummy variable with a continuous reserve variable and multiply it by the change and level of the Federal Funds rates, expressed as $C(log(reserve)) * ff\_delta$ and $C(log(reserve)) * ff\_policy$, as shown in Table 9. The coefficient of ff_policy is significantly negative at 1% and its absolute value is smaller than 1. The coefficient of cross-term $C(log(reserve)) * ff\_policy$ is positive and the significance level is 10%, indicating that as the international reserves in peripheral countries become more and more, the negative deviation of their interest rate spreads caused by the rise of US interest rates becomes smaller and smaller. High reserves can absorb the fluctuation of peripheral countries' differentials, while low reserves cannot cushion external shocks and will even expand the impacts of the shocks instead.

Table 9: Robustness regression—continuous reserve variable.

	(1)	(2)	(3)
VARIABLES	deviation	deviation	deviation
$deviation(-1)$	0.817***	0.817***	0.801***
	(0.015)	(0.015)	(0.015)
ff_delta	0.135	0.134	0.099
	(0.729)	(0.729)	(0.723)
ff_policy	-0.140***	-0.148***	-0.157***
	(0.035)	(0.036)	(0.037)
$\Delta log(WTI\_spot(-1))$	0.486	0.483	0.311
	(0.731)	(0.731)	(0.741)
$C(log(reserve)) * ff\_delta$	-0.209	-0.207	-0.211
	(0.427)	(0.427)	(0.425)
$C(log(reserve)) * ff\_policy$		0.030*	0.031*
		(0.017)	(0.017)
$\Delta deviation(-1)$			0.078***
			(0.023)
Constant	0.549***	0.551***	0.597***
	(0.062)	(0.062)	(0.063)
Observations	6250	6250	6209
Number of id	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

All the previous regressions are estimated with GMM method. To exclude the possible influences of estimation methods on regression results, GLS estimate with country fixed effect is used to re-estimate the benchmark regression equation. The grouping criteria between high and low reserve groups are consistent with those of the baseline regression. The results are shown in Table 10. The interest rate differentials with 1-lag period are all positive significantly at 1% level, which means that there is a convergence of the differentials. The permanent change of the Federal Funds rates has a significant impact on the spreads and most of the significance level is 1%. The coefficients of this variable are between -1 and 0, which proves that the monetary policy of peripheral countries is not independent. The oil price shocks do not cause significant fluctuations in interest rate spreads. The coefficients of cross-term $D_{low} * ff\_policy$ are significantly negative at least at 5% level, indicating that low reserves increase the expected currency depreciation rates and then increase the negative deviation degree of risk-adjusted interest rate differentials after US increases its policy rates. The change of interest rate differentials with 1 lag ($\Delta deviation(-1)$) is significantly positive. Regardless of the estimation methods, the baseline regression results are still robust.

To avoid the possible influences of the 2008 financial crisis and its subsequent impacts, I exclude 2008 and 2009, obtaining a sub-sample spanning from 2010 to 2020. The sub-sample is grouped using the same method of classifying high and low reserve groups as the benchmark regression. Again, I use the GMM method for estimation. The results obtained are shown in Table 11. It is obvious to see that the results are still robust. The coefficient of $D_{low} * ff\_policy$ is negative and significant at 1% level, proving that low reserves cannot buffer the fluctuations of interest rate spreads once again.

Table 10: Robustness regression—GLS estimate with country fixed effect.

	(1)Reserve	(2)Reserve	(3)Reserve	(4)Reserve	(5)Reserve ratio	(6)Reserve ratio
VARIABLES	deviation	deviation	deviation	deviation	deviation	deviation
$deviation(-1)$	0.842***	0.817***	0.816***	0.800***	0.817***	0.801***
	(0.006)	(0.007)	(0.007)	(0.008)	(0.007)	(0.008)
ff_delta	0.091	0.114	0.046	-0.039	-0.530	-0.419
	(0.324)	(0.370)	(0.526)	(0.526)	(0.543)	(0.543)
ff_policy	-0.099***	-0.140***	-0.081*	-0.087*	-0.177***	-0.189***
	(0.033)	(0.038)	(0.045)	(0.045)	(0.050)	(0.050)
$\Delta log(WTI\_spot(-1))$		0.482	0.479	0.308	0.505	0.331
		(0.416)	(0.416)	(0.417)	(0.416)	(0.417)
$D_{low} * ff\_delta$			0.129	0.222	1.202	0.933
			(0.736)	(0.736)	(0.738)	(0.739)
$D_{low} * ff\_policy$			-0.144**	-0.152**	-0.168***	-0.175***
			(0.060)	(0.060)	(0.059)	(0.059)
$\Delta deviation(-1)$				0.078***		0.077***
				(0.012)		(0.012)
Constant	0.457***	0.549***	0.555***	0.602**	0.551***	0.597***
	(0.036)	(0.042)	(0.042)	(0.043)	(0.042)	(0.043)
Country fixed effect	YES	YES	YES	YES	YES	YES
Observations	7422	6250	6250	6209	6250	6209
Number of id	12	12	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

Finally, all the explained variable of the previous regressions is the risk-adjusted interest rate differentials ($deviation/x_{i,t}$). As described in Section 2.2, the differentials consist of four components: $r_{i,t}$, the nominal interest rate of peripheral country i's securities with a certain maturity priced in i's domestic currency at time t; r^*_t, the nominal interest rate of US dollar-denominated securities of the same maturity at time t; $\delta_{i,t}$, expected depreciation rates of peripheral country i's domestic currency at time t; $\rho_{i,t}$, country risks of peripheral country i at time t, measured by Credit Default Swap spreads. In order to further study the transmission process of interest rate shocks and confirm that the reserves do act on the expected depreciation rates to influence the interest rate differentials, in this part, I change the explained variable into the "unadjusted interest rate differentials" (int_dif): $g_{i,t} = r_{i,t} - r_t^*$, where both domestic and US interest rates are defined as above. In this case, considering the change of the definition of the dependent variable, I add two additional explanatory variables: the expected currency depreciation rates of peripheral countries ($dep_{i,t}$) and the spreads of Credit Default Swap that measure sovereign risks ($cdss_{i,t}$). The regression equation is as follows:

$$\begin{aligned} g_{i,t} = \alpha + \theta g_{i,t-1} + \gamma_1 ff\_delta_t + \gamma_2 ff\_policy_t + \gamma_3 D_{low} * ff\_delta_t \\ + \gamma_4 D_{low} * ff\_policy_t + \lambda \Delta g_{i,t-1} + \sum_{j=1}^{n} \phi_j Z_{jt} + \delta dep_{i,t} + \rho cdss_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{6}$$

where $g_{i,t}$ is the unadjusted interest rate differential of peripheral country i at time t. $g_{i,t-1}$ is the unadjusted interest rate differential of peripheral country i at time $t-1$. $ff\_delta_t, ff\_policy_t, D_{low}, Z_{jt}$ are defined as those in the baseline regression. $\Delta g_{i,t-1}$ is the change of unadjusted interest rate differential of peripheral country i at time $t-1$. $dep_{i,t}$ is the weekly percentage change of the exchange rate of peripheral country i's currency/US dollar at time t. $cdss_{i,t}$ is the spreads of Credit Default Swaps of peripheral country i at time t. Here, the only one grouping criterion for classifying high and low reserve groups is the reserve amounts. The results obtained using Eq.(6) are shown in Table 12.

Table 11: Robustness regression—excluding 2008 and 2009.

	(1)Reserve	(2)Reserve	(3)Reserve	(4)Reserve	(5)Reserve ratio	(6)Reserve ratio
VARIABLES	deviation	deviation	deviation	deviation	deviation	deviation
$deviation(-1)$	0.840***	0.831***	0.829***	0.804***	0.831***	0.806***
	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
ff_delta	0.414	0.493	-0.009	-0.099	-0.24	-0.257
	(0.546)	(0.624)	(0.784)	(0.812)	(0.579)	(0.595)
ff_policy	-0.103***	-0.138***	-0.078**	-0.085**	-0.160***	0.177***
	(0.029)	(0.035)	(0.037)	(0.037)	(0.043)	(0.042)
$\Delta log(WTI\_spot(-1))$		0.587	0.606	0.294	0.615	0.305
		(0.806)	(0.806)	(0.821)	(0.810)	(0.825)
$D_{low} * ff\_delta$			1.245	1.335	1.592	1.499
			(1.261)	(1.277)	(1.328)	(1.360)
$D_{low} * ff\_policy$			-0.158***	-0.176***	-0.138***	-0.146***
			(0.051)	(0.050)	(0.048)	(0.047)
$\Delta deviation(-1)$				0.133***		0.131***
				(0.021)		(0.021)
Constant	0.480***	0.504***	0.514***	0.602**	0.507***	0.576***
	(0.051)	(0.057)	(0.058)	(0.043)	(0.057)	(0.058)
Observations	6602	5539	5539	5539	5539	5512
Number of id	12	12	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

The coefficient of 1-lag unadjusted interest rate differentials ($int\_dif(-1)$) is significantly positive at 1% level, indicating that the differentials tend to converge. Most of the coefficients of ff_policy are significantly negative at 10% level and their absolute value are less than 1, which means the dependence of monetary policy of peripheral countries. This paper focuses on the cross-terms of the reserve dummy and the Federal Funds rates. It can be seen that neither the cross-term $D_{low} * ff\_delta$ nor the cross-term $D_{low} * ff\_policy$ is significant, which proves the hypothesis of this paper: International reserves affect the risk-adjusted interest rate differentials by working on the expected depreciation rates of peripheral countries' currencies. Specifically, when the US raises interest rates, low reserves increase the expected domestic currency depreciation rates. As a result, the risk-adjusted interest rate differentials deviate more negatively from the original value. Nonetheless, once the explained variable is replaced with the unadjusted differentials and it no longer contains the expected depreciation rates, international reserves will no longer have significant effects on such differentials. The reason behind is that the explained variable – the unadjusted interest rate differentials – no longer includes the path that reserves can work on, that is, the expected depreciation rates of domestic currencies. Therefore, the coefficients of $D_{low} * ff\_delta$ and $D_{low} * ff\_policy$ re not significant. My hypothesis is confirmed once again from another one angle.

Table 12: Robustness regression—unadjusted interest rate differentials.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	int_dif	int_dif	int_dif	int_dif	int_dif
$int\_dif(-1)$	0.998***	0.997***	0.997***	0.997***	0.993***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
ff_delta	-0.062	-0.067	-0.089	-0.089	-0.07
	(0.058)	(0.068)	(0.101)	(0.101)	(0.102)
ff_policy	-0.011***	-0.006*	-0.006*	-0.007*	-0.003
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)
$\Delta log(WTI\_spot(-1))$		-0.080	-0.079	-0.083	-0.059
		(0.057)	(0.057)	(0.057)	(0.055)
$D_{low} * ff\_delta$			0.044	0.043	0.049
			(0.137)	(0.137)	(0.139)
$D_{low} * ff\_policy$			0.002	0.003	0.00081
			(0.005)	(0.005)	(0.005)
$\Delta int\_dif(-1)$				-0.010	-0.011
				(0.018)	(0.018)
dep					0.008***
					(0.002)
$cdss$					-0.003
					(0.009)
Constant	-0.001	0.004	0.004	0.004	0.602***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.063)
Observations	7479	6269	6269	6268	6209
Number of id	12	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

3.4 Reserves, capital control and the international transmission of interest rate shocks

The impacts of monetary policy in the central country on the domestic interest rates of the peripheral countries can be partly cushioned by capital control. In the classical "Trilemma", a country cannot simultaneously have independent monetary policy, fixed exchange rate regime and fully open capital account. In other words, as long as a country implements floating exchange rate regime, it can achieve both goals of free capital flows and monetary policy autonomy. Or as long as a country implements capital control, it can achieve both goals of fixed exchange rate regime and monetary policy independence.

Table 13: Capital account openness and international transmission of interest rate shocks.

	(1)Full sample, kaopen	(2)Full sample, kaopen	(3)Floating EX sample, kaopen	(4)Floating EX sample, kaopen	(5)Full sample, ka	(6)Full sample, ka	(7)Floating EX sample, ka	(8)Floating EX sample, ka
VARIABLES	deviation	deviation	deviation	deviation	deviation	deviation	deviation	deviation
$deviation(-1)$	0.811***	0.811***	0.812***	0.811***	0.811***	0.816***	0.812***	0.821***
	(0.016)	(0.015)	(0.017)	(0.016)	(0.016)	(0.017)	(0.017)	(0.016)
ff_delta	-0.030	-0.041	0.105	0.114	-0.336	-0.430	-1.302	-1.372
	(0.666)	(0.668)	(0.953)	(0.959)	(0.596)	(0.601)	(1.268)	(1.270)
ff_policy	-0.135***	-0.136***	-0.127**	-0.128**	-0.157***	-0.165***	-0.084*	-0.098**
	(0.046)	(0.050)	(0.054)	(0.058)	(0.040)	(0.043)	(0.045)	(0.049)
$\Delta log(WTI\_spot(-1))$	1.226	0.529	1.456	0.888	1.229	-0.696	1.380	0.344
	(0.824)	(0.938)	(0.954)	(1.196)	(0.824)	(0.716)	(0.951)	(0.974)
$D_{NC} * ff\_delta$	-0.121	-0.091	-0.195	-0.190	0.326	0.427	1.865	1.923
	(1.415)	(1.418)	(1.642)	(1.648)	(1.408)	(1.406)	(1.889)	(1.886)
$D_{NC} * ff\_policy$	0.016	0.018	0.004	0.006	0.056	0.070	-0.080	-0.058
	(0.050)	(0.054)	(0.055)	(0.060)	(0.047)	(0.052)	(0.054)	(0.057)
$\Delta deviation(-1)$	0.067***	0.127***	0.070***	0.129***	0.067***	0.090**	0.071***	0.088**
	(0.024)	(0.034)	(0.025)	(0.036)	(0.024)	(0.040)	(0.025)	(0.038)
$D_{NC} * log(WTI\_spot(-1))$		1.068		0.823		3.316**		1.911
		(1.490)		(1.729)		(1.495)		(1.797)
$D_{NC} * deviation(-1)$		-0.000813		0.000658		-0.009		-0.015
		(0.019)		(0.020)		(0.019)		(0.021)
$D_{NC} * deviation(-1)$		-0.082*		-0.079*		-0.031		-0.024
		(0.045)		(0.047)		(0.049)		(0.049)
Constant	0.574***	0.574***	0.583***	0.584***	0.574***	0.577***	0.587***	0.586***
	(0.064)	(0.062)	(0.072)	(0.070)	(0.064)	(0.063)	(0.072)	(0.071)
Observations	5709	5709	4902	4902	5709	5709	4906	4906
Number of id	12	12	12	12	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

In this section, I delve into the question of "Trilemma or Dilemma" and make the following extensions. First, I use the KAOPEN index of Chinn and Ito (2006, 2008) and the ka index of Fernandez et al. (2015) to measure the level of capital control in the 12 countries. These two indexes are often used by many scholars such as Han and Wei (2018). Second, my data covers the period from 2008 to 2020, while most of the studies mentioned above focus on the end of the 20th century and 2000-2009. The latest data makes this paper timely and many global financial innovations occur in this period. Third, unlike the quarterly or monthly data used in most previous papers, this paper uses high-frequency weekly data to capture potential dynamic adjustment process that may be ignored by low-frequency data. Fourth, I enrich the research on the "Trilemma" and

"Dilemma". To deal with the problem of financial market fragility brought by the financial integration, many countries have included financial stability into the policy goals of the "Trilemma". I include international reserves in the discussion of the "Trilemma", exploring the role of reserves in maintaining financial stability and the role of reserves and capital control combined in the international transmission of interest rate shocks.

Table 14: Robustness regression—continuous KAOPEN index variable.

	(1)Full sample	(2)Full sample	(3)Floating EX sample	(4)Floating EX sample
VARIABLES	deviation	deviation	deviation	deviation
$deviation(-1)$	0.810***	0.842***	0.811***	0.848***
	(0.016)	(0.031)	(0.017)	(0.034)
ff_delta	-2.353	-2.324	-3.143	-3.105
	(1.608)	(1.616)	(2.198)	(2.215)
ff_policy	-0.031	-0.044	0.033	0.018
	(0.063)	(0.064)	(0.072)	(0.073)
$\Delta log(WTI\_spot(-1))$	1.195	-0.881	1.396	-0.950
	(0.825)	(1.684)	(0.954)	(2.204)
$KAOPEN * ff\_delta$	3.933	3.831	4.984	4.861
	(3.485)	(3.487)	(4.123)	(4.138)
$KAOPEN * ff\_policy$	-0.160	-0.159	-0.287	-0.267
	(0.106)	(0.107)	(0.216)	(0.217)
$\Delta deviation(-1)$	0.068***	0.111*	0.071***	0.123*
	(0.024)	(0.061)	(0.025)	(0.066)
$KAOPEN * log(WTI\_spot(-1))$		3.857		4.145
		(3.458)		(4.106)
$KAOPEN * deviation(-1)$		-0.052		-0.063
		(0.049)		(0.052)
$KAOPEN * deviation(-1)$		-0.065		-0.079
		(0.089)		(0.095)
Constant	0.577***	0.569***	0.589***	0.582***
	(0.064)	(0.063)	(0.072)	(0.071)
Observations	5709	5709	4902	4902
Number of id	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

Capital control may influence the transmission of interest rate shocks through several channels. First, it works on the short-term and long-term effects of the Fed's monetary policy actions on peripheral countries' risk-adjusted interest rate differentials. In traditional Trilemma, when a country implements floating exchange rate regime and allows free capital flows, its monetary policy should be independent. In this case, when the US policy interest rates rise, the domestic interest rates in peripheral countries will not go up but will stay the same, $\mathrm{d}r_{i,t}/\mathrm{d}ff_t$=0. Second, the dynamic adjustment of interest rate differentials may also be affected by capital flow mobility. The more open the capital account is, the faster the differentials move towards steady-state equilibrium. In summary, to explore whether the international transmission of interest rates depends on capital account openness, I multiply the no control dummy variable by the change of the Federal Funds rates (ff_delta) and the level of Federal Funds level (ff_policy). To explore whether the dynamic adjustment is affected by the capital flow mobility, I add the cross-term $D_{NC} * x_{i,t-1}$ and cross-term $D_{NC} * \Delta x_{i,t-1}$. I also add the cross-term of oil price shocks and the no capital control dummy variable $D_{NC} * \Delta log(WTI\_spot(-1))$ to test the role of free-flowing capital in other exogenous shocks. The regression equation is as follows:

$$x_{i,t} = \alpha + \theta_1 x_{i,t-1} + \gamma_1 ff\_delta_t + \gamma_2 ff\_policy_t + \gamma_3 D_{NC} * ff\_delta_t + \gamma_4 D_{NC} * ff\_policy_t \\ + \lambda_1 \Delta x_{i,t-1} + \sum_{j=1}^{n} \phi_j Z_{jt} + \theta_2 D_{NC} * x_{i,t-1} + \lambda_2 D_{NC} * \Delta x_{i,t-1} + D_{NC} * \sum_{j=1}^{n} \phi_j Z_{jt} + \varepsilon_{i,t} \tag{7}$$

where $x_{i,t}, x_{i,t-1}, ff\_delta_t, ff\_policy_t, \Delta x_{i,t-1}, Z_{jt}$ are defined the same as above. As for D_{NC}, I use two methods measuring capital control: the KAOPEN index of Chinn and Ito (2006, 2008), whose value ranges from 0 to 1. The closer it is to 1, the more free the capital flows will be. The closer it is to 0, the more restricted the flows will be. The ka index of Fernandez et al. (2015) is also between 0 and 1. The closer it is to 1, the more capital control; otherwise, the less. Then, I sort these two indexes in ascending order, taking 1/2 as the grouping threshold, and obtain the no control dummy variable using KAOPEN index and ka index. For no capital control group, $D_{NC} = 1$. For capital control group, $D_{NC} = 0$. The effects of capital account openness on interest rate transmission will be reflected on the coefficients of the cross-term $D_{NC} * ff\_delta_t$ and cross-term $D_{NC} * ff\_policy_t$ in Eq.(7). If the "Trilemma" holds, when US policy rates rise, domestic interest rates in peripheral countries will remain constant, $\mathrm{d}r_{i,t}/\mathrm{d}ff_t = 0$ instead of $\mathrm{d}r_{i,t}/\mathrm{d}ff_t > 0$. Therefore, for the no control group, its interest rate differentials should deviate more negatively and the coefficient of cross-term should be significantly negative. The influences of capital account openness on the dynamic adjustment of interest rate differentials will be reflected on the coefficients of the cross-terms $D_{NC} * x_{i,t-1}$ and $D_{NC} * \Delta x_{i,t-1}$.

The regression results are shown in Table 13. Columns (1) and (2) use the full sample grouped with the KAOPEN index. Columns (3) and (4) use the floating exchange rate regime sample grouped with the KAOPEN index. Columns (5) and (6) use the full sample grouped with the ka index. Columns (7) and (8) use the floating exchange rate regime sample grouped with the ka index. Similar to the previous results, the short-term effects of the US interest rate change on the interest rate differentials are not obvious (the coefficient of ff_delta is not significant). The long-term effects of the permanent change of the Federal Funds rates on the differentials are significant at least at the 5% level. It is of great concern that the cross-terms are not significant, especially the cross-term of the no control dummy variable and Federal Funds rate level ($D_{NC} * ff\_policy$). I explained before that according to the theory of Trilemma, the coefficients of cross-terms should be significantly negative, because floating exchange rate regime, along with free capital flows, offers independence to peripheral countries. Thus, domestic interest rates $r_{i,t}$ will not follow the rise of US interest rates and remain unchanged. Th risk-adjusted interest rate differentials should deviate towards -1 or a more negative direction. But now the cross-term is not significant, indicating that even under the floating exchange rate regime, $r_{i,t}$ is still rising, $\mathrm{d}r_{i,t}/\mathrm{d}ff_t > 0$. The monetary policy of peripheral countries lacks independence. This happens to coincide with Rey (2015) "Dilemma", that is, floating exchange rate regime cannot provide independence for monetary policy and there is no independence as long as capital flows freely.

Then I do a robustness test. In Table 14, I replace the dummy variable (D_{NC}) with the continuous KAOPEN index variable and add it to the cross-term. The KAOPEN

Table 15: Cross-term coefficients summary.

	No capital control group ($D_{NC} = 1$)	Capital control group ($D_{NC} = 0$)
Low reserve group ($D_{low} = 1$)	$\beta_{1,1}$ and $\beta_{2,1}$	$\beta_{1,2}$ and $\beta_{2,2}$
High reserve group ($D_{low} = 0$)	$\beta_{1,3}$ and $\beta_{2,3}$	$\beta_{1,4}$ and $\beta_{2,4}$

index is a standardized index, so I do not need to perform additional standardization on it. Column (1) and (2) use the whole sample. Column (3) and (4) use floating exchange rate regime sample. The results are similar to those in Table 13. The coefficient of interaction term $kaopen * ff\_policy$ is not significant rather than significantly negative. We can conclude that no matter what exchange rate regime is, with the higher KAOPEN index (less capital control), peripheral countries' interest rates are still on the rise.

However, for countries that aim to achieve their macroeconomic goals by maintaining financial stability, while pursuing independent monetary policy goal, they also need to take into account the question of how to keep the interest rate spreads between the domestic and the international stable. Earlier I have proved that the low reserves cannot buffer interest rate shocks while high reserves can, so I study further that which combination of the reserves and capital control regimes can provide both monetary policy independence and the stability of the interest rate differentials. I remove all the cross-terms in Eq.(7) and let γ_1 and γ_2 in Eq.(7) be the following equations respectively:

$$\begin{aligned} \gamma_1 &= \beta_{1,1} D_{low,NC} + \beta_{1,2} D_{low,C} + \beta_{1,3} D_{high,NC} + \beta_{1,4} D_{high,C} \\ \gamma_2 &= \beta_{2,1} D_{low,NC} + \beta_{2,2} D_{low,C} + \beta_{2,3} D_{high,NC} + \beta_{2,4} D_{high,C} \end{aligned} \tag{8}$$

where the grouping criterion for dividing high and low reserve groups is the reserve amounts. When reserves are low and there is no capital control, $D_{low,NC} = 1$, and $D_{low,NC} = 0$ for the rest; When reserves are low and there is capital control, $D_{low,C} = 1$ and $D_{low,C} = 0$ for the rest; When reserves are high and there is no capital control, $D_{high,NC} = 1$ and $D_{high,NC} = 0$ for the rest; When reserves are high and there is capital control, $D_{high,C} = 1$ and $D_{high,C} = 0$ for the rest. Table 15 summarizes the meanings of coefficients. After replacing γ_1 and γ_2 and deleting all cross-terms in Eq.(7), the following regression equation can be obtained:

$$\begin{aligned} x_{i,t} = \alpha + \theta x_{i,t-1} + \lambda \Delta x_{i,t-1} + \sum_{j=1}^{n} \phi_j Z_{jt} + \beta_{1,1} D_{low,NC} * ff\_delta_t + \beta_{1,2} D_{low,C} * ff\_delta_t \\ + \beta_{1,3} D_{high,NC} * ff\_delta_t + \beta_{1,4} D_{high,C} * ff\_delta_t + \beta_{2,1} D_{low,NC} * ff\_policy_t \\ + \beta_{2,2} D_{low,C} * ff\_policy_t + \beta_{2,3} D_{high,NC} * ff\_policy_t + \beta_{2,4} D_{high,C} * ff\_policy_t + \varepsilon_{i,t} \end{aligned} \tag{9}$$

Table 16 shows the regression results of Eq.(9). Column (1) and (2) use the full sample grouped by reserve amounts and KAOPEN index. Column (3) and (4) use the floating exchange rate regime sample grouped by reserve amounts and KAOPEN index. Column (5) and (6) use the full sample grouped by reserve amounts and ka index. Column (7) and (8) use floating exchange rate regime sample grouped by reserve amounts and ka index. As can be seen from the Table 16, the coefficients of cross-terms ($\beta_{1,1}, \beta_{1,2}, \beta_{1,3}, \beta_{1,4}$) are not significant. I focus on comparing the coefficients of cross-terms ($\beta_{2,1}, \beta_{2,2}, \beta_{2,3}, \beta_{2,4}$). My conclusions are as follows: 1. $\beta_{2,1} < \beta_{2,3}, \beta_{2,2} < \beta_{2,4}$[7]: It proves that low reserves increase

[7]Doing t-test for H0: $\beta_{2,1} < \beta_{2,3}$ and H0: $\beta_{2,2} < \beta_{2,4}$, t-statistics are significant at least at 5%.

the expected domestic currency depreciation rates while high reserves reduce it, resulting in the larger negative deviation of risk-adjusted interest rate differentials for the low reserve group than the high reserve group. 2. $\beta_{2,2} < \beta_{2,1}, \beta_{2,4} < \beta_{2,3}$[8]: In the "Dilemma", monetary policy is independent as long as there is capital control, that is, the domestic interest rates in peripheral countries are not affected by US monetary policy. Hence, the interest rate differentials deviate more negatively from the original value when domestic interest rates ($r_{i,t}$) do not rise under capital control. In the absence of capital control, monetary policy is not independent and the interest rates in peripheral countries follow the rise of US interest rates. In that case, the rise of domestic interest rates makes the differentials deviate less negatively from the original value. 3. $\beta_{2,4}$ is not significant, which proves that in this case, the interest rate shocks from the United States cannot affect the interest rate differentials of peripheral countries. The combination of capital control and high reserves can help countries not only achieve the policy goal of monetary policy independence, but also maintain the stability of risk-adjusted interest rate spreads. This is because higher reserves can reduce the expected domestic currency depreciation rates, offsetting part of the negative deviation of the differentials. This negative deviation results from the negative difference between the rising US interest rates and unchanged domestic interest rates (independent monetary policy).

Table 16: Capital control regimes combined with reserves.

	(1)Full sample, kaopen	(2)Full sample, kaopen	(3)Floating EX sample, kaopen	(4)Floating EX sample, kaopen	(5)Full sample, ka	(6)Full sample, ka	(7)Floating EX sample, ka	(8)Floating EX sample, ka
VARIABLES	deviation	deviation	deviation	deviation	deviation	deviation	deviation	deviation
$deviation(-1)$	0.815***	0.807***	0.816***	0.808***	0.815***	0.805***	0.816***	0.809***
	(0.015)	(0.016)	(0.016)	(0.017)	(0.015)	(0.016)	(0.016)	(0.017)
$\Delta log(WTI\_spot(-1))$	1.273	1.238	1.501	1.466	1.229	1.247	1.418	1.413
	(0.819)	(0.819)	(0.948)	(0.948)	(0.822)	(0.822)	(0.951)	(0.951)
$\Delta deviation(-1)$	0.064***	0.068***	0.067***	0.071***	0.064***	0.069***	0.068***	0.072***
	(0.023)	(0.023)	(0.024)	(0.024)	(0.023)	(0.023)	(0.025)	(0.025)
$D_{low,NC} * ff\_delta(\beta_{1,1})$	-0.617	-0.600	-0.534	-0.532	-0.284	-0.251	0.810	0.859
	(1.434)	(1.430)	(1.545)	(1.541)	(1.642)	(1.637)	(1.712)	(1.712)
$D_{low,C} * ff\_delta(\beta_{1,2})$	2.649	2.681	0.659	0.708	-0.505	-0.479	-2.677	-2.664
	(1.689)	(1.670)	(1.687)	(1.664)	(1.138)	(1.121)	(2.122)	(2.096)
$D_{high,NC} * ff\_delta(\beta_{1,3})$	1.014	0.919	0.999	0.916	0.390	0.290	-0.054	-0.066
	(2.429)	(2.433)	(2.575)	(2.576)	(1.986)	(1.981)	(2.436)	(2.432)
$D_{high,C} * ff\_delta(\beta_{1,4})$	-0.612	-0.537	-1.108	-0.982	-0.321	-0.245	0.097	0.118
	(0.708)	(0.702)	(1.018)	(1.023)	(0.670)	(0.662)	(0.956)	(0.964)
$D_{low,NC} * ff\_policy(\beta_{2,1})$		-0.071		-0.094		-0.076		-0.00075
		(0.048)		(0.058)		(0.045)		(0.044)
$D_{low,C} * ff\_policy(\beta_{2,2})$		-0.153***		-0.148**		-0.188***		-0.126**
		(0.048)		(0.058)		(0.045)		(0.044)
$D_{high,NC} * ff\_policy(\beta_{2,3})$		0.249***		0.253***		0.255***		0.245***
		(0.056)		(0.060)		(0.062)		(0.060)
$D_{high,C} * ff\_policy(\beta_{2,4})$		0.039		0.019		0.090*		0.075*
		(0.048)		(0.050)		(0.053)		(0.046)
Constant	0.485***	0.585***	0.492***	0.596***	0.487***	0.591***	0.494***	0.592***
	(0.051)	(0.063)	(0.056)	(0.073)	(0.051)	(0.065)	(0.056)	(0.072)
Observations	5709	6209	4902	4902	5709	5709	4906	4906
Number of id	12	12	12	12	12	12	12	12

***significant at 1%, **significant at 5%, * significant at 10%.

[8]Doing t-test for H0: $\beta_{2,2} < \beta_{2,1}$ and H0: $\beta_{2,4} < \beta_{2,3}$, t-statistics are significant at least at 10%.

4 Concluding remarks

As the gradual financial integration among the global financial markets, especially after the Global Financial Crisis, the interest rate shocks from the central country have become the key risks that emerging markets and developing countries focus on. And the traditional "Trilemma" has been doubted and expanded because of changing macroeconomic challenges and policy goals of different countries in different times. A new policy goal, financial stability, has been repeatedly proposed. In response to the financial vulnerability caused by the Sudden Stop in international capital flows and capital flight crisis, many countries (such as Mexico, South Korea, Brazil and Russia) have accumulated many international reserves to buffer and manage it. In this paper, I further study the impacts of monetary shocks brought by the change of the Federal Reserve policy interest rates on risk-adjusted interest rate differentials and simple interest rate differentials in peripheral countries and the shock absorption ability of international reserve hoarding. I use the weekly data of 12 countries from 2008 to 2020. The GMM method and GLS method with country fixed effect are used to estimate the regression equations. I also provide empirical evidence on the "Trilemma" or "Dilemma" that floating exchange rate regimes do not provide monetary policy independence. Besides, this paper focuses on the role of capital control in the international transmission of interest rates and provides some ideas on the policy goals of how to improving financial stability and maintain the policy autonomy.

Different from other literature, this paper uses high-frequency weekly data to capture more accurate interest rate transmission path and degree as well as more precise buffer effects. However, due to the statistical frequency of some variables, for example, the monthly reserve data, quarterly GDP and annual capital control index, the conclusions of this paper cannot be completely veracious. Of course, I expect other scholars to build higher-frequency indexes and wish that statistical bureaus publish higher-frequency data, so that this paper will probably offer researchers and policy makers clearer insights and policy suggestions.

My results show that there is a negative relationship between the US policy interest rates and the (risk-adjusted and unadjusted) interest rate differentials for peripheral countries. However, it is not a "1 to 1" effect because the peripheral countries with dependent monetary policy follow the US to adjust their own domestic interest rates. The countries with high reserves have a smaller negative deviation from the original interest rate differential value under interest rate shocks, which means that high reserves can reduce the volatility of the interest rate differentials when involved in the monetary shocks. In contrast, low reserves will magnify the volatility. My explanation is that when a low reserve peripheral country is hit by a currency shock, its expected currency depreciation will move up much more, causing a greater negative shift in risk-adjusted interest rate spreads. However, for the high reserve countries, the negative deviation is smaller because the expected currency depreciation increases less. The three impulse response diagrams show more intuitively that the risk-adjusted interest rate differentials of high reserve countries fluctuate less and take shorter time to reach the steady-state equilibrium when they are hit by the shocks. I also find that changes in the US yield curve and oil prices cannot cause significant fluctuations in interest rate spreads, unlike the change of the dollar value, the exchange rate shocks that can be hedged by reserves through reducing currency depreciation risks. Next, this paper verifies the role of exchange rate regimes and capital control regimes combined with reserves in the interest rate transmission. I find that even if the peripheral countries adopt floating exchange rate regime, as long as they do not carry on capital control, their domestic interest rates still follow the change of the US interest rates, which proves the "Dilemma". When capital control coordinates reserve hoarding, peripheral countries can implement their own monetary policy (they can choose to keep their interest rates unchanged) and have stable risk-adjusted interest rate differentials that are immune to interest rate shocks. The reason is that capital control provides policy independence and the reduced currency depreciation resulting from high reserves offsets the negative difference between unaltered domestic interest rates and rising US rates.

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